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PRELIMINARY ENVIRONMENTAL ASSESSMENT ON FORMCOKE COKEMAKING PROCESS

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16. ABSTRACT The report gives results of a preliminary environmental evaluation and assessment of formcoking. The work is based on readily available literature sources, a plant visit, formcoke plant proposal and feasibility study data, and discussions with engineers and operators involved with formcoking. Material balances, calculations, and engineering judgement were used to convert existing data and information into a form that can be used to compare environmental discharges between formcoking and conventional by-product coking. Comparison results are presented. The lack of environmental data on formcoking is noted.

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Abstract

A preliminary environmental evaluation and assessment of formcoking has been made. The work is based on readily available literature sources, a plant visit, formcoke plant proposal and feasibility study data, and discussions with engineers and operators involved with formcoking. Material balances, calculations, and engineering judgement have been used to convert existing data and information into a form whereby comparisons of environmental discharges can be made between formcoking and conventional by-product coking. The results of those comparisons are presented in this report. The lack of adequate environmental data on formcoking is noted.

CONTENTS

Figures v
Tables v

1.0 INTRODUCTION 1

2.0 CONCLUSIONS AND SUMMARY 2
2.1 CONCLUSIONS 2
2.2 SUMMARY 2

3.0 PROCESS DESCRIPTIONS 7
3.1 BY-PRODUCT COKING PROCESS - GENERAL 7
3.1.1 Coal Preparation and Charging 7
3.1.2 Thermal Distillation 10
3.1.3 By-Product Collection 11
3.2 BY-PRODUCT COKING PROCESS - INLAND STEEL 12
3.3 FORMCOKING PROCESS - FMC, KEMMERER, WYOMING 13

4.0 EXISTING AND PROPOSED FORMCOKE PLANT POLLUTANT STREAMS AND ENVIRONMENTAL CONTROLS SYSTEMS 21
4.1 EXISTING PLANT - FMC, KEMMERER, WYOMING 21
4.1.1 Pollutant Types and Control Technology 21
4.1.2 Pollutant Emission Rates 27
4.2 PROPOSED PLANT - INLAND STEEL, EAST CHICAGO, INDIANA . . . 31
4.2.1 Process Differences - Inland vs. FMC 32
4.2.2 Environmental Control Differences - Inland vs. FMC. 34
4.3 ADEQUACY OF PROPOSED PLANT ENVIRONMENTAL CONTROLS 34

5.0 ENVIRONMENTAL ASPECTS - FORMCOKING VERSUS CONVENTIONAL COKING . 42
5.1 GENERAL 42
5.2 COMPARISON OF CRITERIA AIR POLLUTANTS 43
5.3 ORGANIC AIR EMISSIONS 46
5.4 WASTEWATER AND SOLID WASTE DISCHARGES 48
5.5 TRACE ELEMENT RECOVERY IN FORMCOKE PROCESS 51

6.0 DATA GAPS 59

7.0 REFERENCES 62

FIGURES

Number		Page
3-1	Schematic diagram of by-product coke battery	8
3-2	Flow sheet showing the major steps in the by-product coking process	9
3-3	Typical layout of a pipeline-charged battery	14
3-4	The Coaltek^{R} preheating and pipeline charging system	15
3-5	Wyoming FMC Coke Plant - Fluid bed pyrolysis section (front end)	16
3-6	Wyoming FMC Coke Plant - Mixing, briquetting, curing and coke section (back end)	17
4-1	Process flow diagram for proposed formcoke demonstration plant	33

TABLES

Number		Page
2-1	COMPARISON OF ENVIRONMENTAL DISCHARGES CONVENTIONAL VERSUS FORMCOKING	5
4-1	POLLUTANT SOURCES, CONTROL TECHNOLOGY, DISPOSAL MEDIA FMC PLANT, KEMMERER, WYOMING	22
4-2	FMC - AIR EMISSION SOURCES	29
4-3	PROPOSED PLANT AIR EMISSION SOURCES AND REGULATIONS	36
4-4	WASTEWATER PRETREATMENT STANDARDS FOR NO. 11 BATTERY	39
4-5	EQUALIZATION TANK EFFLUENT NO. 11 BATTERY	40
5-1	COMPARISON OF PARTICULATE EMISSIONS	44
5-2	A COMPARISON OF POTENTIAL NO_x EMISSIONS FROM AMMONIA PROCESSING	47
5-3	WORKER EXPOSURES TO BENZENE SOLUBLE ORGANICS	49
5-4	A COMPARISON OF WASTEWATER FROM THE FORMCOKING AND CONVENTIONAL COKING	50
5-5	A COMPARISON OF THE RATES OF SOLID WASTE GENERATION IN FORMCOKING AND CONVENTIONAL COKING	52
5-6	TRACE ELEMENTS - ESTIMATED VOLATILITY.	54
5-7	TRACE ELEMENT RECOVERY IN GASIFICAION WATER FOR TWO COMMERCIAL PROCESSES	55
5-8	TRACE ELEMENT RECOVERY IN GASIFICATION WATER RTI GASIFICATION TESTS	56
5-9	A COMPARISON OF TRACE ELEMENTS IN THE WASTEWATER OF INLAND BATTERY NO. 11 AND RTI GASIFICATION TESTS	58
6-1	POTENTIAL SOURCES OF ENVIRONMENTAL EMISSIONS	61

1.0 INTRODUCTION

This report was prepared in response to a request from the Department of Energy (DOE) through the Environmental Protection Agency to do a preliminary environmental assessment of formcokemaking. The impetus for this preliminary environmental assessment was a proposal from Inland Steel to DOE to solicit government funded assistance for the design and construction of a new formcoke plant. The depth of the preliminary assessment has been limited greatly by the time available to complete the work, and the fact that time did not permit any sampling and analytical work to be completed. The reported conclusions are based on data existing when the study began. Material balances, calculations, and engineering judgement have been used to convert these limited, existing data into a form whereby comparisons of environmental discharges can be made between formcoking and conventional coking.

Subsequent to completion of this report DOE recommended to Congress that initial incremental funding for detailed design of the Inland Steel formcoke plant be provided. While initial funding was approved in Congressional committee action, this project never received funding consideration before the full House or Senate. Inland Steel officially withdrew its proposal to DOE in 1981.

2.0 CONCLUSIONS AND SUMMARY

2.1 CONCLUSIONS

1) Formcoke production will eliminate many sources of hazardous air emissions which are present in conventional coking and are difficult to effectively control. The formcoking process is more amenable to air pollution control in that there are fewer potential emission sources and the age deterioration of process equipment is not as severe as that which occurs in conventional coke batteries.

2) Formcoke production has the potential of significantly reducing worker exposure to carcinogenic air emissions, when compared to conventional coking.

3) Formcoking is expected to produce the same amount or up to 50 percent more wastewater to be treated and sludge/solid waste for which it is desirable to find uses.

4) With formcoking some trace element and polycyclic organic matter concentration may occur in the recycled wastewater similar to coal continuous conversion processes. Data are insufficient to determine the extent of buildup and to identify satisfactory wastewater treatment technology.

5) Existing data are not sufficient for a complete environmental assessment of formcoking.

2.2 SUMMARY

A preliminary environmental evaluation and assessment of formcoking has been made. The work is based primarily on readily available literature sources, a visit to the FMC Corporation formcoking plant in Kemmerer, Wyoming, data available in the Inland Steel proposal to the Department of Energy (DOE), data from the feasibility study of the proposed plant by Davy-McKee Corporation, and discussions with various engineers and operators involved with formcoking.

The existing plant was examined to identify the waste streams leaving the plant and the pollutant levels in those streams. Because of the limited time available to complete the project, it was necessary to depend on pollutant

data available from test work previously completed. These available data were not comprehensive; as a result there were many data gaps.

The proposed plant description as provided in the Inland Steel proposal to DOE was compared to the existing plant. Differences in the process equipment, and pollution control facilities were examined. In particular, the proposed plant will be about four times larger than the existing plant, and be processing an Illinois coal instead of a Wyoming coal. With the Illinois coal the process will not produce enough tar for binder. Supplementary tar will have to be processed and added. Inland plans to design the plant to operate in either an air mode similar to FMC or in an oxygen/steam mode that will produce a higher heating value by-product gas stream than at FMC. In either mode the gas will be recovered for other plant uses.

In the gas recovery process more efficient particulate removal is expected in the Inland plant than is achieved at the FMC plant. Since no gas desulfurization is performed at FMC and a Stretford system is proposed for the Inland plant, SO_x emissions from the proposed plant will be much lower. The FMC plant discharges wastewater to a holding evaporation pond. The proposed Inland facility final wastewater treatment will be in a publicly owned treatment works. Pretreatment in the form of ammonia and cyanide stripping is planned. Cooling of the recycled wastewater stream will be achieved by non-contact water streams.

The adequacy of proposed pollution controls for the proposed Inland installation was also studied. It is necessary to consider, however, that the final plant design is not available and that the proposed equipment is little more than conceptual at present. Plans for controlling particulates and sulfur oxides offer the potential for compliance provided proper specifications and selection of design parameters are made. Present NO_x regulations appear to affect none of the proposed plant sources. Ammonia and cyanide incineration, however, is expected to produce more NO_x than would be allowed from the smallest source regulated in Indiana. Ammonia recovery could be practiced to reduce NO_x emissions. No air pollution standards for polycyclic organics currently exist, and no data were available to analyze quantities of potential organic emissions from formcoking.

With respect to potential discharges from the proposed Inland plant, wastewater samples were requested from the FMC plant, but they were not received in time for analysis and inclusion in this report. In qualitative terms many

of the components present in conventional coking wastewater are expected to be present in formcoking wastewater, but quantities may be different. Since specific wastewater treatment equipment has not as yet been selected, an assessment of the potential for compliance with pretreatment standards has not been possible. Also, plans for solid waste handling are not defined at this time, again preventing an assessment of potential for compliance.

Finally, estimated environmental discharges from formcoking were compared with those estimated for conventional coking. Table 2-1 summarizes the results of the comparisons. No direct measurement of polycyclic organic matter (POM) emissions was available from formcoking for comparison with conventional coking. Worker exposures to benzene soluble particulates have been measured at the FMC plant. In general the FMC measurements show lower worker exposures than have been found in conventional coke plants. This comparison suggests that POM emissions may also be lower for formcoking.

What is not shown in the numerical comparisons is the expected greater ease of maintaining control of air pollution for formcoking as compared to conventional coking. Control of air pollution from the batch conventional coking process (particularly hazardous organic pollutants) is highly dependent on work practice and also tends to deteriorate with coke battery age as a result of battery dimensional changes. These factors are not expected to play as big a role in air pollution control for the continuous formcoking process.

For normal operations, particulate emissions are expected to be about the same for formcoking as a well controlled coke oven battery. A well controlled battery for all particulate sources is an ideal case that may be difficult to achieve because of the batch nature of the process. SO_x emissions are expected to be about equivalent. Since ammonia is usually not incinerated for conventional coking, the actual and proposed formcoking will have higher NO_x emissions from this source. Alternatively ammonia could be recovered from formcoking similarly to the operation of conventional coking.

In the air mode, wastewater quantities will equal conventional coking. In the operating mode (steam/oxygen) with high heating value gas recovered, the formcoke process is expected to generate up to 50 percent more wastewater to treat than conventional coking (when compared on the basis of recovering benzene from both processes). Presumably the wastewater from each can be treated to give the same discharge quality. For plants that might have to provide full wastewater treatment instead of pre-treatment followed by dis-

TABLE 2-1. COMPARISON OF ENVIRONMENTAL DISCHARGES
CONVENTIONAL VERSUS FORMCOKING

Environmental discharge	Conventional coking kg/Mg coke	Formcoking kg/Mg coke
Particulates	0.7-7.5(1)	1.1(2)
SO_x	2.2	2.2
NO_x		
from NH_3	13(3)	4-14(3)(4)
from other combustion	---	---
Wastewater	550-1,460 (Including byproduct recovery)	630-1,400 Air Mode 1,410-2,210 Steam/O_2 Mode (Including byproduct recovery)
Sludge and solid residues	38(5)	29.8(6) Air Mode 24.7(6) Steam/O_2 Mode
POM (as indicated by B(a)P)	0.004	No data
Occupational exposure to benzene solubles	150-500 $\mu g/m^3$	50-161 $\mu g/m^3$

(1) Low value is for a well controlled battery for all particulate sources, and is an ideal case.
(2) Conservative estimate, could be decreased if necessary.
(3) Zero if recovered instead of incinerated.
(4) There are indications that the lower carbonization temperature formcoke process will favor lower formation of ammonia.
(5) Includes coke breeze (~ 36 kg/Mg) much of which is used as a low value fuel rather than as coke.
(6) Does not consider possible reuse of formcoke sludges.

charge to a publicly owned treatment work, the cost could be a significant impact to overall process economics.

Sludge/solid waste quantities for which no uses have been identified are also higher for formcoking than conventional coking. Ultimate disposal of the sludge/solid waste is a key issue. In conventional coking an analogous solid byproduct is coke breeze. In most cases coke breeze is reintroduced to the iron and steelmaking process or sold to others. At present it is not known whether calcinate thickener sludge could be handled in a similar manner.

A full assessment of formcoking would necessarily examine trace element emissions (heavy metals, etc.). Though no direct measurements have been made on a formcoke plant, some data from gasification processes with similar fluidized bed operations were reviewed. The data are presented not to say a problem with trace elements exists, but to establish the importance of a more thorough investigation.

3.0 PROCESS DESCRIPTIONS

3.1 BY-PRODUCT COKING PROCESS - GENERAL

Figure 3-1 illustrates the major equipment used in the process in a schematic diagram of a by-product coke battery. A flow sheet is provided in Figure 3-2 to give an overview of the process from coal charging to by-product recovery. This operation will be discussed in greater detail in three major subprocesses: coal preparation and charging, thermal distillation and pushing, and by-product recovery.

3.1.1 Coal Preparation and Charging

The coal that is charged to the by-product coke ovens is usually a blend of two or more low, medium, or high volatile coals that are generally low in sulfur and ash. Blending is required to control the properties of the resulting coke, to optimize the quality and quantity of by-products, and to avoid the expansion exhibited by some types of coal that may cause excessive pressure on the oven walls during the coking process.

Coal is usually received in railroad cars or barges and dumped in the coal storage area. Conveyor belts transfer the coal as needed from the storage pile to mixing bins where the various types of coal are stored. The coal is transferred from the mixing bins to the crusher where it is pulverized to a preselected size between 0.15 and 3.2 mm. The desired size depends on the response of the coal to coking reactions and the ultimate coke strength that is required. For example, low volatile coals coke more readily if the particle size is small, and smaller particles are reported to give greater strength to the coke.

The pulverized coal is then mixed and blended, and sometimes water and oil are added to control the bulk density of the mixture. The prepared coal mixture is transported to the coal storage bunkers on the coke oven batteries as shown in Figure 3-1. A weighed amount or volume of prepared coal is discharged from the bunker into a larry car, a vehicle driven by electric motors which travels the length of the battery top on a wide gauge railroad

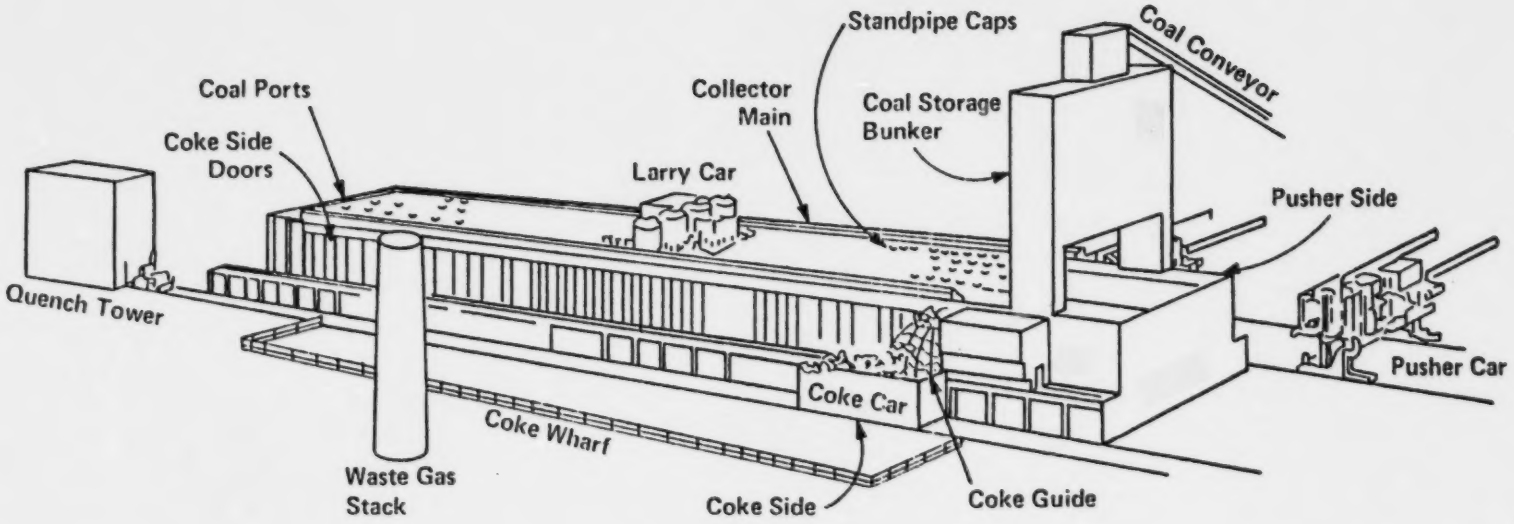


Figure 3-1. Schematic diagram of by-product coke battery.

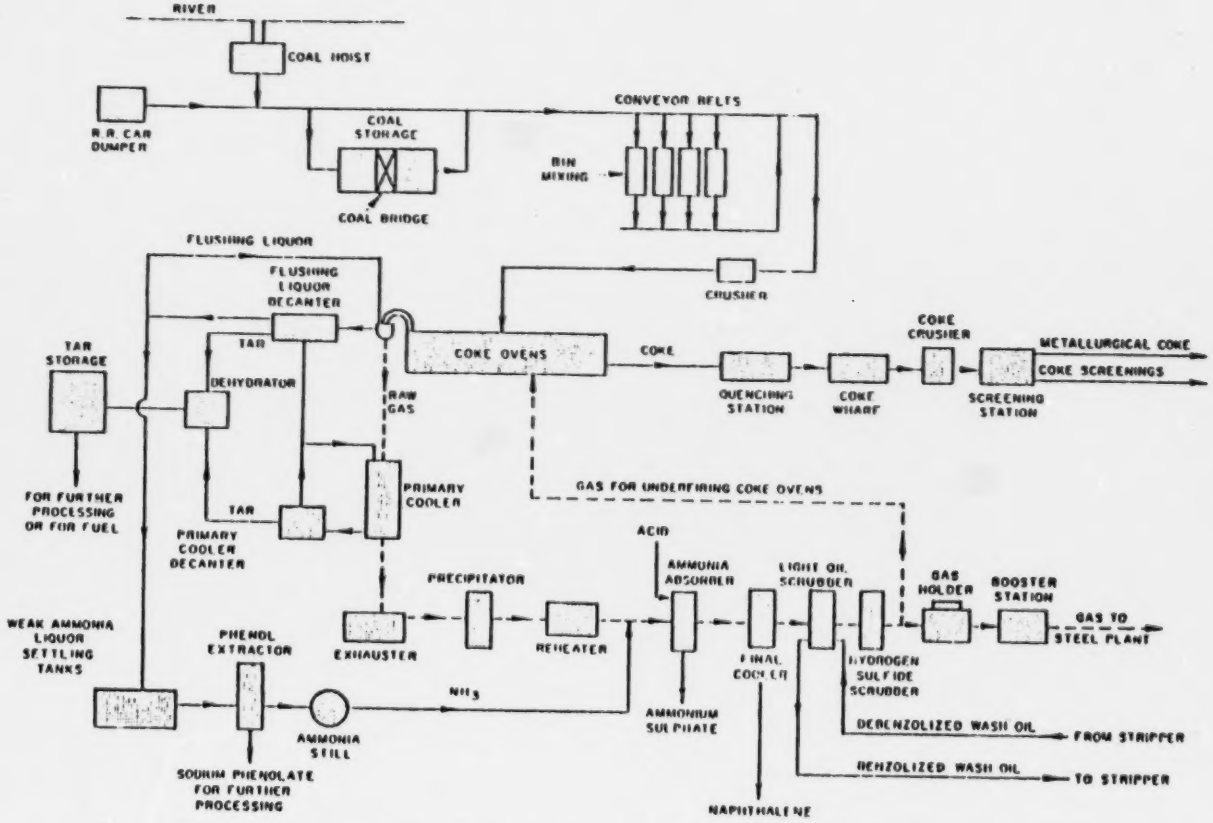


Figure 3-2. Flow sheet showing the major steps in the by-product coking process. (copyright 1971 by United States Steel Corporation)

track. The larry car is positioned over the empty, hot oven, the lids on the charging ports are removed, and the coal is discharged from the hoppers of the larry car through discharge chutes. To prevent gases from escaping during charging, a steam-jet aspirator is used in most plants to draw gases from the space above the charged coal into the collecting main.

3.1.2 Thermal Distillation

The thermal distillation of coal to separate volatile and nonvolatile components takes place in coke ovens that are grouped in batteries. A battery consists of 20 to 100 adjacent ovens with common side walls which are made of high quality silica and other types of refractory brick and contain integral flues. Typically, the individual slot ovens are 11 to 16.8 m long, 0.35 to 0.5 m wide, and 3.0 to 6.7 m high.

Heat for the coking operation is provided by a regenerative combustion system located below the ovens. Because the combustion flue gas contains a significant amount of process heat, two heat regenerators are used for recovery. These regenerators are located below each oven, one for combustion air and one for the combustion waste gas, and the flow is alternated between the two at about 30 minute intervals. The slot ovens operate like chemical retorts that are batch operated, in addition they are fitted with exhaust flues (standpipes), and function without the addition of any reagent.

The operation of each oven in the battery is cyclic, but the batteries usually contain a sufficiently large number of ovens (an average of 57) that the yield of by-products is essentially continuous. The individual ovens are charged and discharged at approximately equal time intervals during the coking cycle. The resultant constant flow of evolved gases from all the ovens in a battery helps to maintain a balance of pressure in the flues, collecting main, and stack. All of the ovens are fired continuously at a constant rate, irrespective of a particular oven's stage in the coking cycle. If damage to the refractory occurs in inaccessible locations, through overheating or expansion of coal, repairs may be extremely difficult. A cooldown takes from 5 to 7 weeks, so a battery shutdown is undertaken only as a last alternative.

After the ovens are filled, coking proceeds for 15 to 18 hours to produce blast furnace coke and 25 to 30 hours to produce foundry coke. The coking time is determined by the coal mixture, moisture content of the coal, rate of underfiring, and the desired properties of the coke. The coking temperatures

generally range from 900 to 1,100°C and are kept on the high side of the range to produce blast furnace coke. Air is prevented from leaking into the ovens by maintaining a positive pressure of about 10 mm water gauge in the collecting main. The gases and hydrocarbons that are evolved during the thermal distillation are removed through the off-take main and sent to the by-product plant for recovery.

At the end of the coking cycle, doors at both ends of the oven are removed and the incandescent coke is pushed out the coke side of the oven by a ram which is extended from the pusher machine. The coke is pushed through a coke guide into a special railroad car, called a quench car. The quench car carries the coke to the end of the battery to a quench tower where it is deluged with water so that it will not continue to burn after being exposed to air. The quenched coke is discharged onto an inclined "coke wharf" to allow excess water to drain and to cool the coke to a reasonable handling temperature.

Gates along the lower edge of the wharf control the rate of coke falling on a conveyor belt which carries it to the crushing and screening system. The coke is then crushed and screened to obtain the optimum size for the particular blast furnace operation in which it is to be used.[1] The breeze (undersize coke) generated by the crushing and screening operations is used in other steel plant processes, stockpiled, or sold.

3.1.3 By-Product Collection

Gases evolved during coking leave the coke oven through the standpipes, pass into goosenecks, and travel through a damper valve to the gas collection main which directs them to the by-product plant. These gases account for 20 to 35 percent by weight of the initial coal charge and are composed of water vapor, tar, light oils, heavy hydrocarbons, and other chemical compounds.

The raw coke oven gas exits at temperatures estimated at 760 to 870°C and is shock cooled by spraying recycled "flushing liquor" in the collection main. This spray cools the gas to 80 to 100°C, precipitates tar, condenses various vapors, and serves as the carrying medium for the condensed compounds. These products are separated from the liquor in a decanter (Figure 3-2) and are subsequently processed to yield tar and tar derivatives.[1]

The gas is then passed either to a final tar extractor or an electrostatic precipitator for additional tar removal. On leaving the tar extractor, the gas carries three-fourths of the ammonia and 95 percent of the light oil originally present when leaving the oven.

The ammonia is recovered either as an aqueous solution by water absorption or as ammonium sulfate salt. Ammonium sulfate is crystallized in a saturator which contains a solution of 5 to 10 percent sulfuric acid and is removed by an air injector or centrifugal pump. The salt is dried in a centrifuge and packaged.

The gas leaving the saturator at about 60°C is taken to final coolers or condensers, where it is typically cooled with water to approximately 24°C. During this cooling, some naphthalene separates and is carried along with the wastewater and recovered. The remaining gas is passed into a light oil or benzol scrubber, over which is circulated a heavy petroleum fraction called wash oil or a coal-tar oil which serves as the absorbent medium. The oil is sprayed in the top of the packed absorption tower while the gas flows up through the tower. The wash oil absorbs about 2 to 3 percent of its weight of light oil, with a removal efficiency of about 95 percent of the light oil vapor in the gas. The rich wash oil is passed to a countercurrent steam stripping column. The steam and light oil vapors pass upward from the still through a heat exchanger to a condenser and water separator. The light oil may be sold as crude or processed to recover benzene, toluene, xylene, and solvent naphtha.[2]

After tar, ammonia, and light oil removal, the gas undergoes a final desulfurization process at some coke plants before being used as fuel. The coke oven gas has a rather high heating value, on the order of 20 MJ/Nm^3 (550 Btu/scf). Typically, 35 to 40 percent of the gas is returned to fuel the coke oven combustion system, and the remainder is used for other heating needs.

3.2 BY-PRODUCT COKING PROCESS - INLAND STEEL

Inland Steel's proposal to the U.S. Department of Energy presented an energy consumption comparison between the Formcoke Process and conventional coking as practiced at their No. 11 battery. As suggested by Inland, their No. 11 battery represents the latest installed technology. The No. 11 battery cokemaking differs from the general description of cokemaking presented in Section 3.1 in several respects.

A simple statement of the difference is that coal to be charged to the battery is preheated in a fluidized bed prior to charging to the ovens, thus decreasing the oven coking time. Use of a preheater means additional processing equipment is required and additional potential sources of pollutant

discharges must be controlled. The additional pollutant discharge may not be a net increase per unit weight of coke, since a preheater increases the production capacity of a given size battery. Figure 3-3 is a diagram of the cokemaking process for a battery with a coal preheater and using pipeline charging, Figure 3-4 presents a flow diagram of the Coaltek® preheating and pipeline charging system similar to that used on No. 11 battery.[2,3]

After crushing and screening coal is charged to the preheater. The fluidized bed is heated by gas produced from combustion of coke oven gas. Coal leaving the flash dryer reaches a bulk temperature 177° to 260°C (350° to 500°F).[2] Preheated coal is separated from the gas stream by cyclones and conveyed to charging bins. The gas stream is further cleaned in a wet scrubber prior to discharge to the atmosphere.

In the pipeline system, coal is charged to individual ovens with a conveying stream of steam. To prevent contamination of flushing liquor with coal fines, the charging liquor is kept separate in a bifurcated collecting main. After charging, the preheated coal coking process proceeds in a similar manner to conventional coking except that the coking cycle time may be reduced as much as 40%.

3.3 FORMCOKING PROCESS - FMC, KEMMERER, WYOMING

The design of the proposed Inland Steel Formcoke plant is based on the design and operating experience gained from the FMC plant in Kemmerer, Wyoming. A process description of the FMC plant is given here to provide a basis for comparison with the proposed Inland plant design, and to examine improvements and changes made to integrate the process with a steel plant. The following paragraphs of process description were extracted from the referenced technical paper.[4]

The process flow sequence for the FMC Coke at Kemmerer is shown on Figures 3-5 and 3-6. Coal unloaded from incoming rail cars is crushed to minus 4 mesh and pneumatically conveyed to the Catalyzer, the first of the series of fluid bed processing units. In this vessel, heat to dry and condition the feed coal is furnished by an internal steam coil and by partial oxidation of the coal at a temperature of 149°C (300°F). With the non-caking, sub-bituminous coal used, the primary function of the Catalyzer is to remove the inherent moisture from the coal; about 22%.

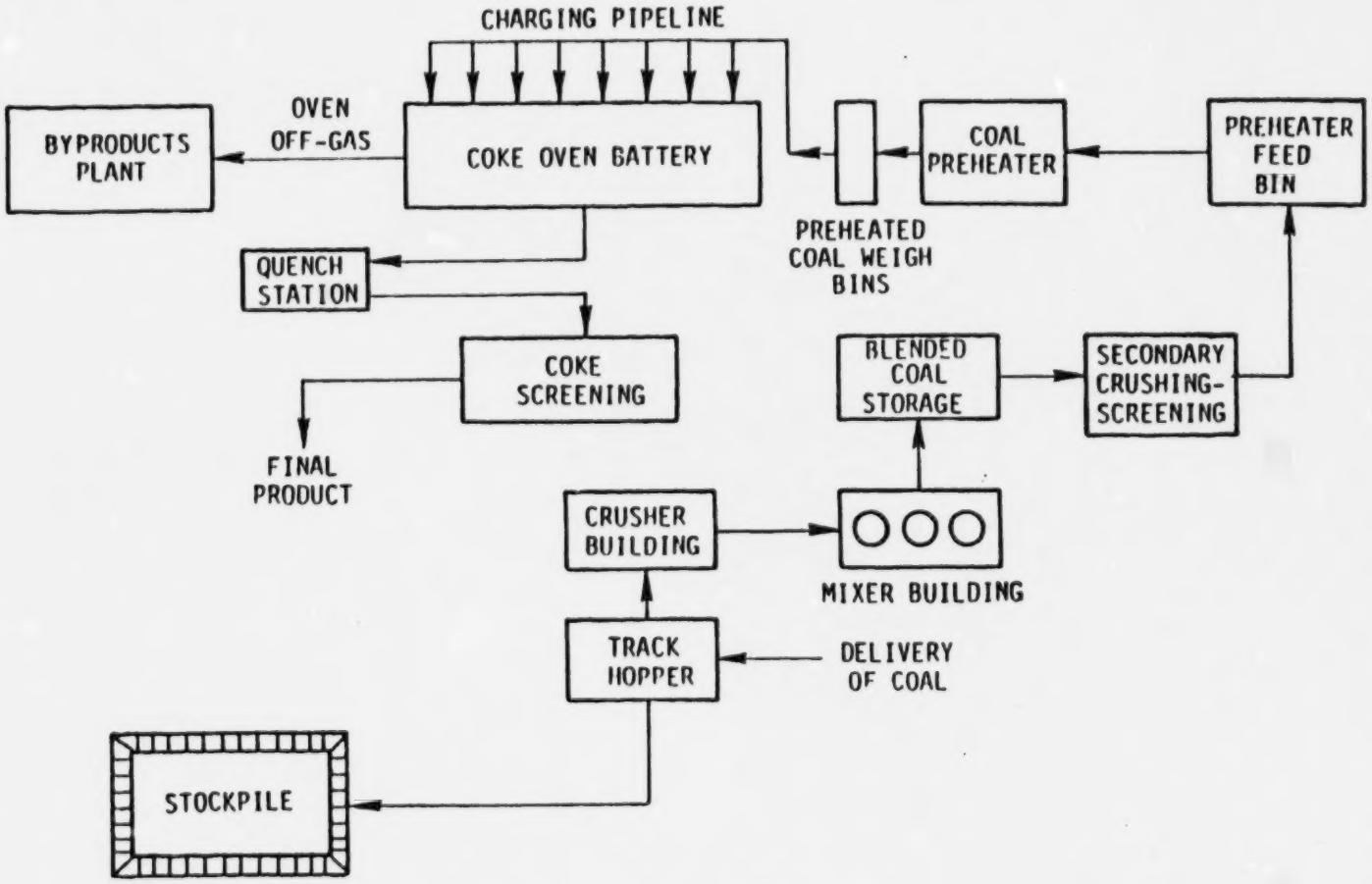


Figure 3-3. Typical layout of a pipeline-charged battery.

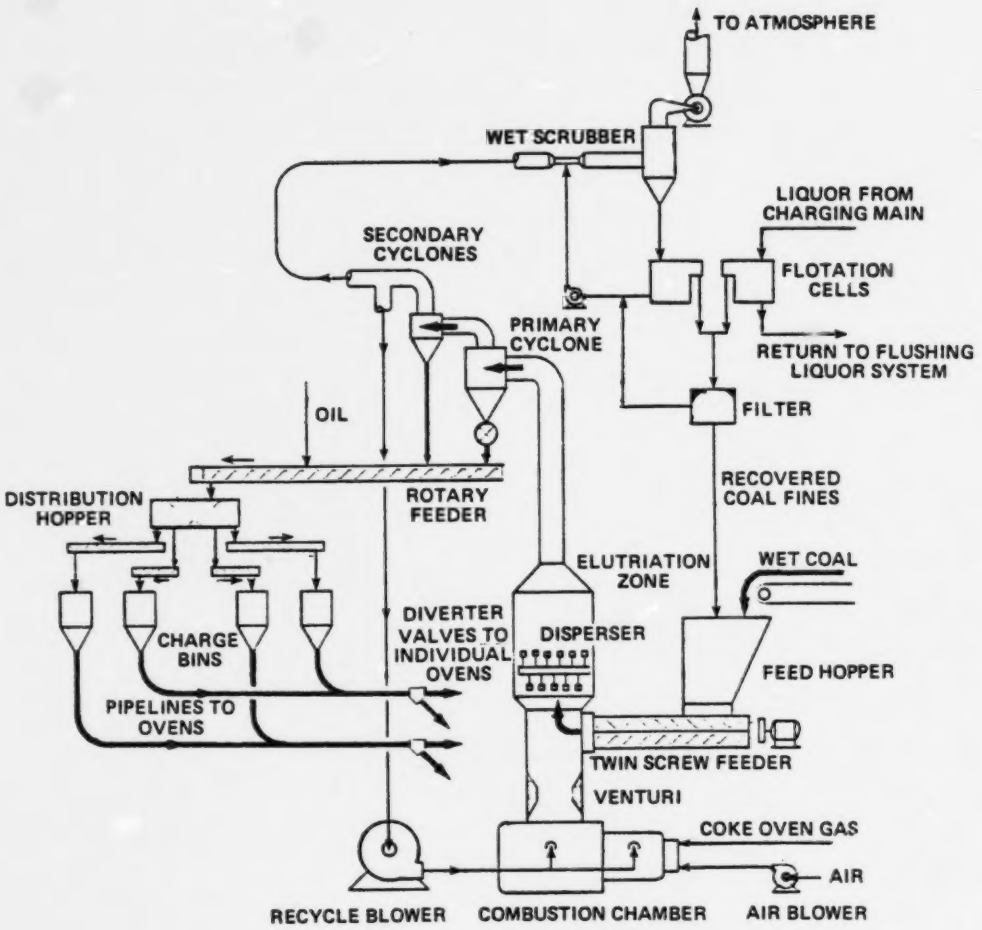


Figure 3-4. The Coaltek^{R} preheating and pipeline charging system. Ref. 3

Figure 3-5.[4] Wyoming FMC Coke Plant - Fluid Bed Pyrolysis Section (Front End)

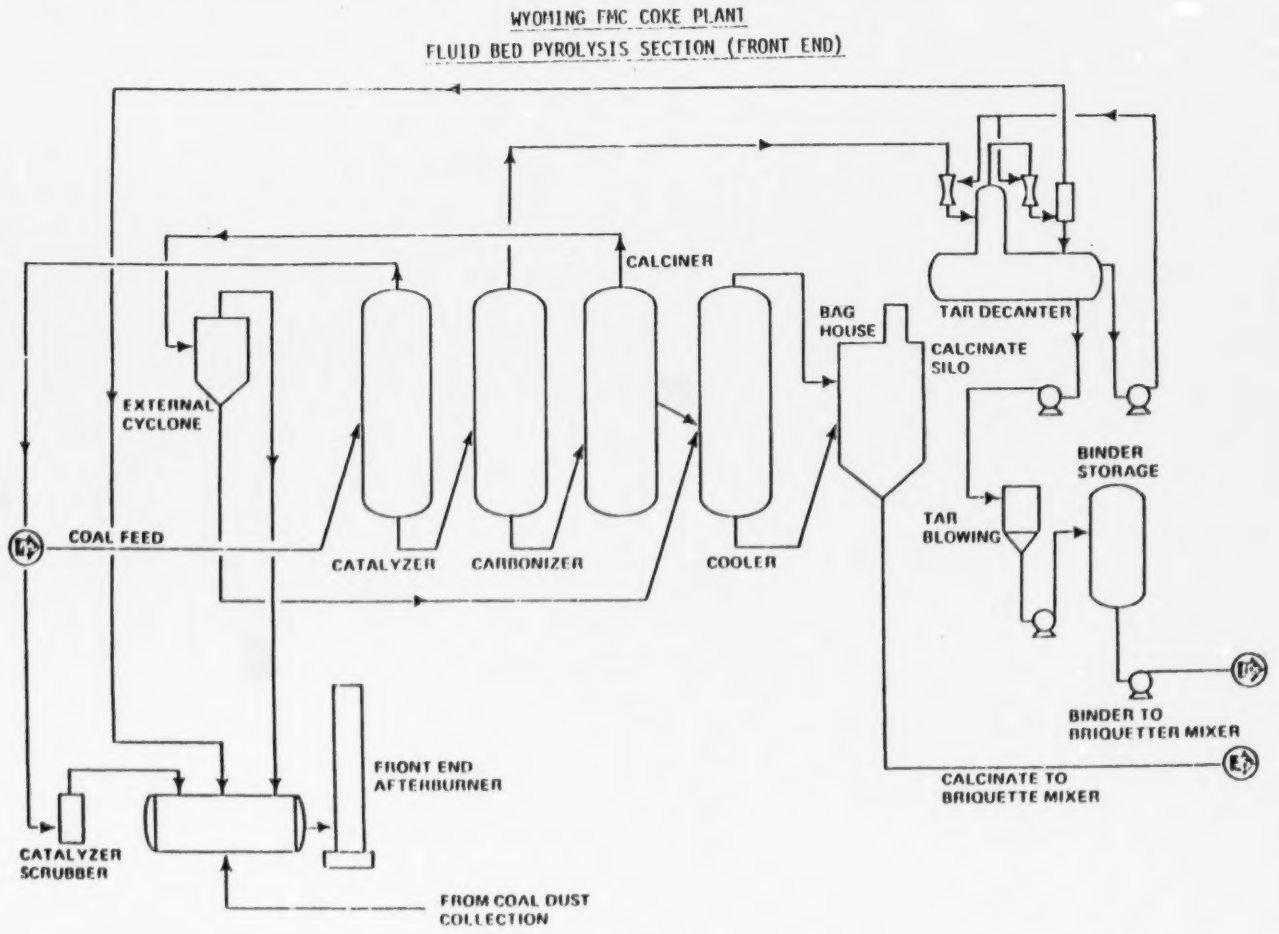
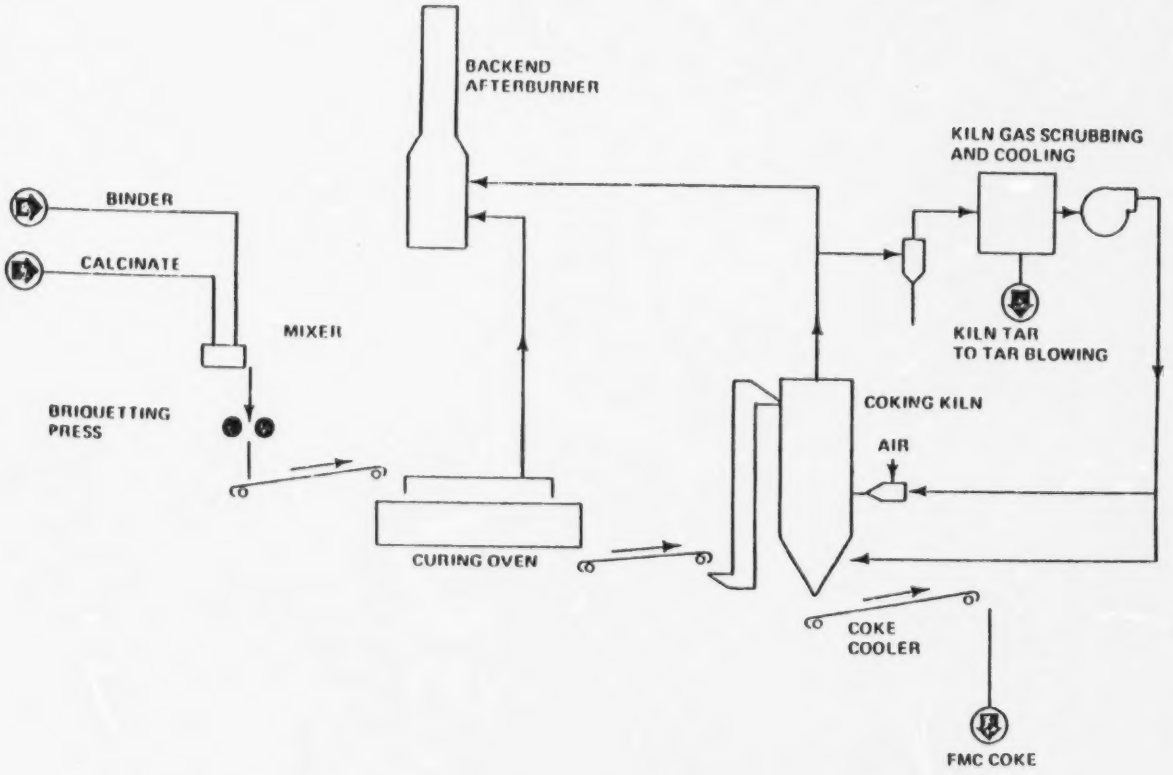


Figure 3-6.[4] Wyoming FMC Coke Plant - Mixing, Briquetting, Curing and Coke Section (Back End).



Treatment in the Catalyzer partially oxidizes the coal to prevent agglomeration in the succeeding pyrolysis beds, an important step when processing a caking coal. The oxidation reactions in the Catalyzer also tend to improve briquette quality. The off-gases from the Catalyzer, containing coal fines, pass through internal and external cyclones, a condenser-scrubber and then through the Front End Afterburner.

Conditioned coal from the Catalyzer is then transferred pneumatically to the Carbonizer where it is heated in a fluid bed to 480°C (900°F) by air oxidation of a small amount of the coal. The fluidizing gas consists of air, steam, and products of combustion in controlled portions. This low temperature carbonization breaks the coal down into tar, char, gas, and water. The quality and the quantity of tars formed are functions of the coal utilized, fluid bed temperature, oxygen concentration, and prior Catalyzer operating conditions. Conditions are carefully controlled to optimize tar quality and yield. The tar and gas are carried overhead through an internally mounted cyclone and into a quenching station where the hot gas is rapidly cooled to 77°C (170°F) by contact with large quantities of recirculating aqueous liquor in a Venturi scrubber. The cooled gases are then contacted with more liquor in a second Venturi scrubber to separate tar from the noncondensable gases. The condensed tar and liquor are accumulated and separated in two decanters. Waste gas from the Carbonizer is then incinerated in the Front End Afterburner. An aqueous stream is bled from the scrubbing system and also oxidized in the Front End Afterburner.

The partially devolatilized char is transported pneumatically from the Carbonizer by inert gas into a third fluid bed, the Calciner. Fluid bed combustion of a small proportion of the char in the Calciner generates sufficient heat to raise the bed temperature to about 815°C (1500°F). The temperature and composition of the fluidizing gas, consisting of air and products of combustion, is carefully controlled. The remaining volatiles in the char are released primarily as methane, carbon monoxide, carbon dioxide and hydrogen. The Calciner product is a thin walled, porous, reactive carbon called calcinate with a volatile content of about 3%. (This VM [sic volatile matter] is primarily nitrogen and carbon monoxide.)

The hot gases and dust leaving the Calciner pass through three cyclones in series, one internal and two external. The residual 15.8 k cal per cubic meter (150 Btu per cubic foot gas) is fed to the Front End Afterburner where it provides fuel for the incinerator of the emissions from the Catalyzer and Carbonizer.

The hot calcinate from the Calciner overflows into the fourth fluidized vessel, the Primary Calcinate Cooler, where it is rapidly cooled to 260°C (500°F) by contact with steam generating coils immersed in the fluidized bed.

The calcinate finally passes into the fifth fluid bed vessel, the Secondary Cooler, where it is cooled to 121°C (250°F) before it is pneumatically transported to a storage silo. Gas from the two coolers is vented through the storage silo baghouse.

Inert gas is used as the fluidizing medium in the two calcinate coolers and for pneumatic transport of the catalyzed coal and char. This inert gas is flue gas from the Front End Afterburner which has been water scrubbed and compressed for use throughout the plant.

The wet tar condensed out of the Carbonizer overhead gas is continuously pumped to the tar dehydrators. In the dehydrators, the water is driven out of the tar by a combination of heating, agitation and air blowing. The tar is oxidized and polymerized to increase its softening point to approximately 63°C (145°F) (ring-and-ball test). Condensers control the organic emissions from the blowing operation.

Dehydrated tar and calcinate from the storage silo are combined in a mixer and then pressed into pillow shaped briquettes. The air emissions from this step, tar fume and particulate are controlled by a negative pressure collection system on the mixers and presses. The system discharges through a cyclone to the Front End Afterburner. The briquettes are moved to the Curing Oven, by belt conveyors.

In the Curing Oven, the briquette temperature is raised to 232°C (450°F). During this curing step, the briquette tars are further polymerized, volatiles are evolved, and the briquette strength increased. Part of the volatile material evolved is burned in the oven to furnish the necessary process heat and the excess is incinerated in the Back End Afterburner.

The cured briquettes are conveyed from the curing oven to a shaft kiln where they are coked at high temperatures 815-871°C (1500-1600°F) utilizing part of the hydrocarbons evolved during coking as fuel. Some tar is evolved during coking. This tar is scrubbed from the coke off-gases and recycled to the tar dehydrators where it is converted into binder along with the Carbonizer tar. Excess kiln gas is burned in the Back End Afterburner. Coked briquettes exiting the kiln are air cooled on a steel mesh conveyor and transported to a silo from which they are loaded into rail cars for shipment. A single baghouse is used to control fugitive emissions from operations associated with the during oven discharge, kiln, briquette cooler, storage and rail car loading.

4.0 EXISTING AND PROPOSED FORMCOKE PLANT POLLUTANT STREAMS AND ENVIRONMENTAL CONTROLS SYSTEMS

4.1 EXISTING PLANT - FMC, KEMMERER, WYOMING

This plant was originally built as an experimental coke plant, but now supplies FMC's phosphorous plant in Pocatello, Idaho.[4] The current environmental control equipment was, in general, not installed when the plant was constructed. Instead the environmental control equipment has evolved with changes in the plant's operating status - experimental to commercial in 1971, changes in operating philosophy, environmental regulations, and the availability and cost of energy. In the past several years great steps have been taken to improve the energy efficiency of the operation, which at the same time has improved its environmental control status. Not all the environmental improvements, however, have resulted from the goal of improved energy efficiency. Installation of fugitive dust controls, and steps to reduce water usage and the resulting increasing size of the tarry water pond are examples of improvements strictly of an environmental nature.

4.1.1 Pollutant Types and Control Technology

The existing plant operations have been examined to identify the existing pollutant streams in each of the three media (air, water, land). A plant visit for this purpose was made in February, 1980.[5] This visit plus a recent technical paper are the principal bases for the listing of pollutants and control technology.[4]

For purposes of this preliminary assessment, the plant operations have been divided as follows: coal preparation and handling, pyrolysis, briquetting and coking, and miscellaneous. Table 4-1 presents the identified pollutant streams associated with the various process operations and the applied control technology by media.

For coal preparation and handling, potential emissions to the air are the problem. Screens and conveyor transfer points are controlled with the collected air ducted to one of the plant incinerators. Since a portion of the

TABLE 4-1. POLLUTANT SOURCES, CONTROL TECHNOLOGY, DISPOSAL MEDIA
FMC PLANT, KEMMERER, WYOMING

Operations	Pollutants and control technology		
	Air	Water	Solid waste
Coal preparation & handling			
Crushing, screening, conveyor transfers	Part.* -Incinerator		
Pyrolysis			
Catalyzer	Part., gas, organic vapors-Cyclone, scrubber, incinerator	Scrubbing liquor-Recycled to cooling pond	Solids settled in cooling pond
Carbonizer	Part., light oil, tar, gas-Scrubber, incinerator	Scrubbing liquor-Recycled to tar decanter and tarry water pond, tarry water water incinerated	Tar-Reused after recovery; decanter solids (tar residue)-Landfill
Calciner	Part., organic vapors, gas-Cyclone, incinerator		Cyclone solids are returned to process
Primary & secondary coolers calcinate silo	Part. and gas-Baghouse		Solids recovered are returned to process

*Part. = Particulates

(Continued)

TABLE 4-1. (CONTINUED)

Operations	Pollutants and control technology		
	Air	Water	Solid waste
Briquetting & coking			
Briquette mixers and presses	Part., organic vapors-Cyclone		Solids recovered are returned to process
Conveyor to curing oven, grizzly	Part., organic vapors-Covered conveyor & hoods, no control device		
Curing oven	Tar vapors-Incinerator		
Cured briquette conveyor, kiln grizzly	Part., organic vapors-Covered conveyors and hoods to baghouse		Dust recycled to calcinate surge bin
Coking kiln	Part., tar, gas-Cyclone, scrubber, incinerator, some gas recycled to kiln for fuel value	Scrubbing liquor-Recycled to tar decanter and tarry water pond, tarry water incinerated	Tar-Reused after recovery; decanter solids (tar residue)-Landfill
Coke conveyor, cooler, kiln air locks, coke loading, coke silo	Part. and gas-Covered conveyors and hoods to baghouse		Dust recyled to calcinate surge bin
Tar blowing (binder preparation	Tar, light oil, organic vapors-Scrubber/ condenser	Condenser liquor-Incinerator	

(Continued)

TABLE 4-1. (CONTINUED)

Operations	Pollutants and control technology		
	Air	Water	Solid waste
Miscellaneous			
Inert gas generation	Incinerator waste gas (SO_x, NO_x, organics, part.)-Scrubber	Scrubber liquor-Wastewater pond	Solids settled in pond
Rain water and spills		Runoff water-Directed to pond	Solids result from evaporation

collected particulate matter is combustible, the incinerator produces a partial reduction in discharged particulate.

After screening the coal is conveyed to a storage tank. At the bottom of the tank the coal enters a pneumatic feeder that carries the coal into the pyrolysis section of the plant. From the coal storage tank to the calcinate silo the processed solids are not exposed to the atmosphere; they are conveyed pneumatically from stage to stage. The pyrolysis operations in general produce large gas streams with recoverable energy values. In this plant the main catalyzer function is to dry the coal charge. The gas stream leaving the catalyzer passes through cyclones and a scrubber before going to an incinerator. This gas stream has no fuel value.

Solids removed by the cyclones are returned to the process. Scrubbing liquor is pumped to a settling pond and recycled from there. Settled solids remain in the pond.

Operation of the carbonizer at about 900°F produces a gas stream with organic materials. Tar, light oil (benzene, toluene, xylene), ammonia, methane, carbon monoxide, and many additional organics are produced. An internal cyclone removes particulates and returns them to the fluid bed. Outside the carbonizer the initial cleanup is by two scrubbers in series. Tar and other condensed material is separated from the gas by scrubbing liquor. Non-condensible gases leave the scrubbers and are burned in an incinerator with previously mentioned waste streams. Fuel value of the gas is utilized to incinerate other wastes, and waste heat is recovered to generate process steam.

The scrubbing liquor is recirculated between tar decanters and the scrubber. In the tar decanters, tar and light oil are separated from the scrubbing liquid before the liquid is returned to the scrubbers. A waste stream of tarry water is taken off, as blowdown, to the tarry water pond. From the pond a stream is taken to the incinerator that burns calciner and carbonizer gas as fuel.

Tar recovered at the decanters is the raw material for the binder in the briquettes. Solids that settle in the decanter (tarry residues) are cleaned from the decanter bottom about twice per year. Although FMC is investigating alternative disposal methods, these solids are presently landfilled. The fate of light oils is discussed later in this section.

The calciner, operating at 1500°F, generates a product gas containing carbon monoxide, carbon dioxide, methane, and hydrogen. Particulates entrained in the gas stream are removed by cyclones, and the captured solids are returned to the process. Following the cyclone the gas stream is ducted to the incinerator where it serves as a fuel source.

Calcinate is cooled in two fluidized bed coolers. Particulates and gas emissions leaving with the cooling gas stream are directed to a baghouse where the particulates are removed. The same baghouse also serves the calcinate storage silo. The pneumatic conveying waste gas stream (an inert gas extracted from the incinerator exhaust) serving the pyrolysis units discharges through this baghouse. Solids collected in the baghouse are returned to the process.

As compared to the pyrolysis operations, the briquetting and coking operations have a greater potential for fugitive air emissions. Mixers where the char and binder tar are blended produce dust that is captured by mixer enclosures vented to a cyclone. Because the tar is heated there are some organics emitted as well. Captured solids are returned to the process. Briquetting press emissions are similarly controlled.

The conveyors between the briquette presses and the curing oven are covered and transfer points hooded. Some fugitive air emissions have been noted in this material handling step.[5] Dust is generated through material movement and by a process step (grizzly) that removes webs from the briquettes. The temperature of the briquettes and noted coloration of emissions from the transfer point also suggest the presence of organics. At present there is no provision for cleaning emissions from this material handling step.

The curing oven heats the briquettes to 232°C and the resultant gaseous emissions (containing organics) are recycled within the oven to recover fuel value. The emissions are ultimately discharged through an incinerator.

Cured briquettes leave the curing oven on a covered conveyor and are transferred through another grizzly to the vertical shaft coking kiln. Potential fugitive emissions containing particulates and organics are gathered from the conveyor, grizzly, and transfer points and ducted to a baghouse. Dust removed in the baghouse is recycled to the calcinate surge bin.

The coking kiln heats the cured briquettes to over 815°C (1500°F). Because of the binder material, the offgases contain tar and organic materials. A portion of the generated gas is recycled to the kiln as fuel. Gas cleaning is provided by a cyclone and scrubber. The remainder of the gas is burned

without scrubbing in an incinerator along with the curing oven waste gas stream. Scrubbing liquor is circulated to tar decanters similarly to the carbonizer scrubbing liquor. After separation of the tar, the scrubber liquor is recycled to the scrubber. The kiln is a net consumer of water, but presumably when there is excess scrubber water, it is also bled to the tarry water pond. From there a stream of tarry water is withdrawn to be incinerated. Tar separated at the decanter is reused for binder after dehydration and blowing to polymerize it. Tar residue from the decanter bottom is landfilled. Downstream of the kiln, the kiln air locks, coke cooler, coke conveyors, coke silo, and coke loading operations are covered, hooded, or otherwise vented to capture particulate and gas emissions. The handling operation gas streams are ducted to a baghouse. The collected dust is recycled to the calcinate surge bin.

An additional important step in the briquetting operation is binder preparation. In the tar decanters the scrubber water from the carbonizer and coking kiln gas cleaning systems are treated. In addition to separation of tar, the light oil fraction containing benzene, toluene, and xylene, is also separated. The separated fractions are processed in tar dehydrators that drive off water by heating and air blowing. Along with the water, the light oils are also driven off. Scrubber/condensers applied to the waste gas stream condense water and some of the organics. This waste liquid stream containing recoverable benzene is incinerated. The ultimate fate of the remaining gas stream downstream of the condensers is discharge to the atmosphere.

Among the miscellaneous pollutant sources are inert gas generation and rain water runoff and spills. A portion of the incinerated gas stream from the pyrolysis section of the plant is scrubbed to produce clean inert gas for some process steps. The gas discharged from the incinerator contains particulates, sulfur oxides, nitrogen oxides, and perhaps some small amount of residual organics. Scrubbing liquor is pumped to a wastewater pond for settling. Settled solids remain as a sludge base in this pond. Based on the previously referenced technical paper, rainwater runoff and runoff from spills are directed through ditches to a pond.[4] Presumably, evaporation from this pond leaves a residue of materials carried in the waste streams.

4.1.2 Pollutant Emission Rates

Data available on the potential pollutant emissions from the FMC plant are limited. More data exists on actual emissions from the pollution control

devices, but it is still meager. Aside from fugitive emissions, there are eight principal air emission points. These points are listed in Table 4-2. The fact that waste gas streams from numerous point sources are combined to utilize control devices in common makes it difficult to project potential or uncontrolled emissions.

Table 4-2 lists the approximate gas stream sizes for some of the control devices based on information supplied by Davy-McKee Corporation.[6] The data presented on particulate emissions were extracted from the technical paper by Kulberg et al.[4] and data supplied by FMC personnel during the plant visit. Presumably these represent measured rather than estimated emissions except for the case noted. Total estimated particulate emissions are 7.1 kg/tonne of coke. Since no sulfur removal equipment is installed at the plant and the sulfur-bearing waste gas streams are incinerated, sulfur oxide emissions can be estimated on the basis of a mass balance using sulfur in the coal and coke. The following coal analysis was reported in the paper by Kulberg et al.:[4]

WYOMING SUB-BITUMINOUS COAL USED AT FMC PLANT

	Dry	Wet (as received)
Fixed carbon	52.8	44.5
Sulfur	1.0	0.8
Ash	4.7	3.7
Volatile matter	42.5	33.3
Moisture	--	21.5
Gross heating value	Kcal/gram (10,000 BTU/lb)	

The general FMC plant experience with sulfur content of the produced coke is that about half of the incoming coal sulfur is retained in the coke produced.[7] Based on 2.4 kg of wet coal to produce 1 kg of coke, the estimated emission rate of SO_x reported as SO_2 is 19.2 kg/tonne of coke.

Nitrogen oxide emissions usually are produced as a side effect of fuel combustion in air. Combustion reactions occur in the catalyzer, carbonizer, calciner, coking kiln, curing oven, and the waste incinerators. No measured data is available on these emissions. An estimate might be attempted on the basis of fossil fuel firing in boilers, however, the combustion temperatures in some formcoking operations are much lower. In some of the operations the overall conditions are reducing rather than oxidizing which further complicates an attempt at estimates.

TABLE 4-2. FMC - AIR EMISSION SOURCES

	Front end afterburner	Back end afterburner	Calcinate silo	Calcinate surge bin	Back end baghouse	A Briquette cyclone	B,C Briquette cyclone	Vent condenser
Gas flow rate - scmm[6]*	1,120	770	52	21	671	--	--	--
Particulates - kg/Mg** coke								
Uncontrolled	INSUFFICIENT DATA TO DETERMINE							
Controlled[4]	4.8	0.66	0.19	No data	0.47	0.05	0.86	0.15 (estimated)
SO_x - kg SO_2/Mg coke								
Uncontrolled	19.2		NONE EXPECTED					
Controlled	NO CONTROLS INSTALLED							
NO_x - kg NO_2/Mg coke								
Uncontrolled	1.2+		No data	NONE EXPECTED				
Controlled	NO CONTROLS INSTALLED							
Organics - kg/Mg coke								
Uncontrolled	INSUFFICIENT DATA TO DETERMINE							
Controlled	0	0	No data	No data	No data	No data	No data	No data

*Standard cubic meters per minute.
**Kilograms per megagram (tonne).

At least one source quantity of NO_x can be estimated, that is the combustion of ammonia generated as byproduct gas in the carbonizer. Ammonia in conventional coking is generated at a rate of about 5.0 kg/tonne coke produced. Because of the lower yield of FMC formcoke per unit weight of coal charged as compared to conventional coking, a somewhat higher rate of ammonia generation may be expected for formcoking on a coke rate basis, about 6.2 kg/tonne coke (formcoke). Lower rates of ammonia generation have been reported due to lower reaction temperatures for formcoke.[11] The estimated NO_x (reported as NO_2) from ammonia incineration is in the range of 5 to 17 kg/tonne coke.

As indicated by previous discussion, organics are generated in gas streams throughout the plant. Much of the organic material is recovered for use in the binder, or used otherwise for its fuel value in the process equipment or incinerators. The only available data on organic emissions are those in the paper by Kulberg et al. where the organic emissions from the two afterburners are reported to be zero.[4] Some gas stream composition data were provided for streams prior to incineration, but the effectiveness of the incinerator for specific compounds is not known, nor is the relative quantity of gas in each stream known.

In any case, the organic measurements made in the gas stream would not have been capable of detecting the level of benzene soluble organics, benzo-(a)pyrene, or other potential carcinogens that would be of most interest. The presence or absence of these compounds in the plant emissions is a key issue in the question of whether formcoking is an environmental improvement over conventional coking. Benzo(a)pyrene is particularly important because the Environmental Protection Agency is presently developing regulations to control emissions of this pollutant. Direct measurements of this pollutant are needed for a proper assessment.

The FMC plant claims no wastewater discharges out of the plant boundaries. As a result no NPDES permit is required. Evaporation is one of the primary disposal methods for the wastewater generated. However, even in the arid plant climate their tarry water pond was growing. With the installation of the incinerator a quantity of about 20 gallons per minute is being withdrawn from the pond for incineration.[5] The tarry water pond had grown to 22 acres, but now is 11 acres and shrinking.

Obviously the use of settling ponds leaves a solid residue which ultimately will be handled. At present this material is not reused. The quantity

of settled solids is not known. Tar solids are removed from the tar decanter on a semi-annual basis. The quantity estimated is less than 9 tonnes per year.[5] Considering the compounds present in the tar, this waste would be classified as hazardous. Present practice is land disposal, but plant personnel speculate that this waste could be incinerated or reintroduced to the process.

Over the years a "mountain" of offgrade calcinate, green briquettes, and cured briquettes has grown on the plant property.[5] Reuse of this stockpiled material is thought to be possible with reintroduction at the calcinate silo. Malfunctions and abnormal operating conditions for what at times had been an experimental plant played a role in generating the offgrade materials. With normal plant operations these discharges should be minimized.

4.2 PROPOSED PLANT - INLAND STEEL, EAST CHICAGO, INDIANA

Modifications have been made to the design of the formcoke process to make it more compatible with an integrated steel plant. The production capacity at the FMC plant is about 220 tonnes per day (242 tons) whereas the proposed plant for Inland Steel is about 910 tonnes per day (1000 tons).

The coal to be coked is also different. Inland is planning to use an Illinois No. 6 coal from their No. 1 Mine. The following coal analysis was supplied by Inland.

		Percent
Constituent	Average	Range
Moisture	11.6	10.3-12.4
Volatile matter*	35.3	34.2-36.5
Fixed carbon*	58.5	57.2-59.4
Ash*	6.2	5.6-6.6
Sulfur*	0.87	0.75-1.05

*Dry basis.

As is evident the volatile matter in the Inland coal is lower than the FMC coal, 35.3% as compared to 42.5%; and the ash content is higher, 6.2% as compared to 4.7%. Also the as received moisture for the Inland coal is only 11.6% as compared to 21.5%.

4.2.1 Process Differences - Inland vs. FMC

In reviewing process changes between the FMC plant and the proposed Inland plant, it is important to remember that the proposed Inland design was really only conceptual in nature. Enough work was done to permit only a feasibility study. The flow diagram for the proposed plant is shown in Figure 4-1.

In terms of major differences, two changes qualify. The coal to be used by Inland will not produce sufficient binder material to satisfy production needs. Therefore, supplementary tar will have to be processed to produce a sufficient amount of binder. The importance of the need for supplemental binder is recognized when considering the claim that formcoking might ultimately replace conventional coking. In Inland's case the likely source of additional tar is their conventional coking byproduct recovery. Without conventional coking another binder source must be found. The sufficiency of tar for binder is coal dependent for this process. Preparation of supplemental binder is not shown in Figure 4-1. The preparation process, however, is conceived to be identical to that shown for process generated tar, i.e., the tar is dehydrated by heating and polymerized by air blowing.

The second major difference is that Inland intends to recover the byproduct gas and use it for steam generation or other processes in their steel plant, not just for incineration of the process waste streams. The average heating value of the gas generated in the FMC plant is about 5.6 MJ/m^3 (150 BTU/ft^3).[4] This heating value is significantly lower than byproduct gas produced by conventional coking - 18.6 MJ/m^3 (500 BTU/ft^3). Coke oven gas is used not only for coke battery heating but as a fuel for many other steel plant processes as well.

If Inland desires a higher fuel value byproduct gas, then the plant operating mode will be different than at FMC. Higher fuel value gas can be produced by operating the pyrolysis section of the plant with a fluidizing gas enriched with oxygen and steam. In this mode a byproduct gas with heating value about 13.0 MJ/m^3 (350 BTU/ft^3) can be produced. The expected consequence of operation in this mode is a lower coke yield per unit weight of coal charged. Full-scale plant trials of this mode have not been made.

Another process difference of lesser magnitude in the proposed plant is the use of a coal dryer external to the pyrolysis section of the plant. Coal drying at the FMC plant is accomplished in the catalyzer.

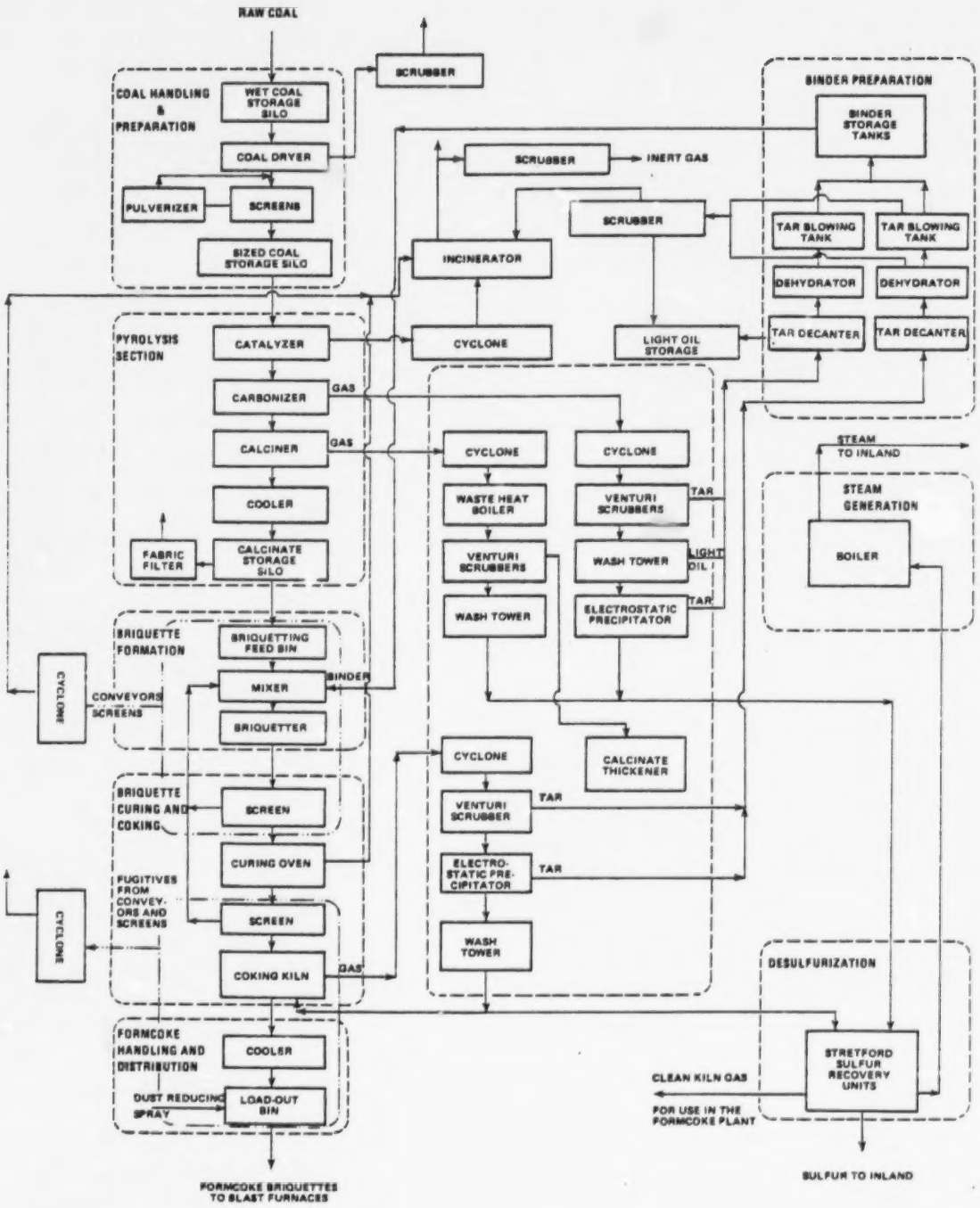


Figure 4-1. Process Flow Diagram for Proposed Formcoke Demonstration Plant.

4.2.2 Environmental Control Differences - Inland vs. FMC

The most readily identifiable difference in environmental control plans for the proposed plant at Inland is the practice of desulfurizing the by-product gas stream. No desulfurization is practiced at the FMC plant. Besides producing a quantity of elemental sulfur there will be an additional wastewater stream generated as a result of pretreatment of the gas or treatment of the recirculated absorbing solution to remove HCN.

In the proposed Inland plant the coal dryer will generate an additional gas stream for treatment. The scrubber proposed for this gas stream will recycle wastewater to the calcinate thickener.

Additional wastewater streams must be recycled and blowdown treated due to the improved gas cleanup (particulate removal) necessary prior to desulfurization of byproduct gas. The conceptual wastewater treatment system design includes steps to strip cyanide and ammonia from waste scrubbing liquor. These operations will generate additional sludge for disposal. Activated sludge pretreatment of the wastewater stream will also generate additional sludge. There will be a discharge of wastewater from the Inland plant as opposed to no discharge from the FMC plant.

Separation of light oil and resultant storage of light oil will mean additional potential for evaporative losses of benzene as compared to the FMC plant where light oil is incinerated.

One other environmental difference is that the scrubbing liquor for gas cleaning in the pyrolysis section and coking kiln will be cooled indirectly by non-contact water at Inland. Direct cooling of scrubbing liquor at the FMC plant presents potential for volatile water contaminants to become airborne.

4.3 ADEQUACY OF PROPOSED PLANT ENVIRONMENTAL CONTROLS

As discussed in Section 4.2.1 of this report, the design for the proposed plant at this time is little more than conceptual. Given that specific design and operating parameters for pollution control systems are not yet determined and that process stream compositions are not accurately defined, it is not possible to pass judgment on the adequacy of the proposed environmental controls. Some preliminary opinions as to sufficiency can be formed by examining the generic types of control systems proposed. Knowing the capabilities of a well designed and operated system that uses the generic type of control and the probable stream composition, allows an opinion of sufficiency to be offered on

the presumption that good engineering judgement is applied in the detailed design.

Table 4-3 presents a listing of the air emission sources for the proposed plant. The governing regulation is also identified. All computations for limiting levels are based on feasibility study process data provided by Davy McKee. In the cases involving combined streams from more than one source, e.g., calcinate silo baghouse, the computation of a limit is based on a "best guess" as to which of the regulations would be governing. Analysis of the particulate sources is the most complicated in that there are many sources controlled by different regulations. The two small sources - coal handling and calcinate silo - controlled by fabric filters should have no problem with compliance. Provided the scrubber applied to the coal dryer exhaust has a sufficiently high pressure drop, it should also achieve compliance.

The available feasibility study data from Davy-McKee had no information on solids content of the waste gas streams being fed to the incinerator serving the curing oven, catalyzer, light oil scrubber, and various material handling sources. The chance for incinerator emissions to achieve compliance for particulates is dependent on the upstream particulate control devices. The similar incinerator at FMC achieves controlled particulate emissions of about 4.8 kg/Mg coke when operating on fuel sources cleaned to a lesser degree than planned at Inland. The estimated limit at Inland is less than 2 kg/Mg. It may be necessary to pretreat some of the contributing particulate streams on which only cyclones have been proposed to achieve higher particulate removal upstream of the incinerator.

The dust control system proposed for controlling emissions from material handling between curing oven and coking kiln, coking kiln air locks, coking conveyors, coke loading, and storage bins may not adequately control particulates, if only a cyclone is applied. A fabric filter is a more effective choice.

Little descriptive information was provided in the Inland proposal related to plans for handling and storing light oil. There are, however, equipment standards that apply to this potential source.

An estimated limit for SO_x emissions resulting from sulfur in the by-product gas streams was made on the basis of the limitation imposed on the No. 11 battery at Inland. The current limit of 463 lbs/hr (210 kg) is equivalent to about 2.2 kg/Mg of coke produced. For the proposed plant the equivalent weight limit would be 84 kg/hr (185 lbs).

TABLE 4-3. PROPOSED PLANT AIR EMISSION SOURCES AND REGULATIONS

Source	Expected pollutant	Control	Governing regulation	Limiting level
Byproduct fuel burning - Steam generation, coal dryer, incinerators, calcinate reheat	NO_x	None	Indiana APC-17	0.2 lbs NO_2/millon BTU heat input (none of the individual sources are large enough to be limited). (1.0 kg/Mg coke)
	SOx	Fuel gas desulfurized, but no SO_x controls	Established by EPA for No. 11 battery	463 lbs SO_2/hr for No. 11 battery (2.2 kg/Mg coke)
Light oil storage and handling	Organics	Unknown	Indiana APC-15	Equipment standard
Coal dryer	Particulate	Scrubber	NSPS	0.03/gr/scfd 1.7 lbs/hr (0.03 kg/Mg coke)
Coal handling	Particulate	Baghouse	Indiana APC-5	48 lbs/hr (0.6 kg/Mg coke)

(Continued)

TABLE 4-3. (CONTINUED)

Source	Expected pollutant	Control	Governing regulation	Limiting level
Calcinate silo	Particulate	Baghouse	Indiana APC-5	42 lbs/hr (0.5 kg/Mg coke)
Steam generation	Particulate	None	Indiana APC-4R	55 lbs/hr air mode (0.7 kg/Mg coke) 73 lbs/hr steam mode (0.9 kg/Mg coke)
Material handling - Cured briquettes and coke	Particulate	Cyclone	Indiana APC-5	43 lbs/hr (0.5 kg/Mg coke)
Incinerator - Curing oven, briquetting fugitives	Particulate	Combustion	Indiana APC-7	117 lbs/hr air mode (1.4 kg/Mg coke) 159 lbs/hr steam mode (1.9 kg/Mg coke)

The data provided on the process flow sheets for COS and estimated H_2S removal capability of the proposed Stretford desulfurization units show emission rates in the range of 1.2 to 1.6 kg SO_2/Mg coke should be achieved. Therefore, the proposed equipment appears to be capable of achieving compliance.

With respect to NO_x emissions none of the individual plant sources appears to have a large enough heat input to qualify for regulation. The estimated limit applying is 1.0 kg/Mg of coke for a minimum sized source burning gas.

Though the incinerator applied to ammonia and cyanide waste gases has not been studied sufficiently to define a size or limiting level, the estimated incinerator ammonia wastes alone would probably exceed 1.0 kg/Mg of coke. This matter is addressed further in Section 5 of this report.

Adequacy of the proposed wastewater treatment controls is difficult to judge for several reasons. One reason is that the proposed wastewater treatment facilities have been described in only vague terms. Some major equipment items have been verbally identified, but the feasibility study done by Davy-McKee did not examine wastewater treatment needs in any depth. A second reason why adequacy is difficult to judge is that Inland Steel need only provide pretreatment of the wastewater to make it acceptable for discharge to a publicly owned treatment works in their vicinity. Exact limitations as of May, 1980 were defined for their No. 11 Battery. Current pretreatment standards and the older limits are listed in Table 4-4.

The wastewater streams from the proposed formcoke plant will likely contain all the various components typically found in conventional coke plant wastewater discharges. The relative quantities of constituents could vary considerably because of the difference in operating (reaction) conditions. Table 4-5 presents an analysis of wastewater from Inland's No. 11 Battery.[9] The analysis is for the equalization tank effluent, a sample point that includes all coke plant waste streams. An examination of wastewater streams in the FMC plant could provide some indication of similarities or differences between conventional and formcoking streams. Samples of wastewater from several process points at the FMC plant were requested, but unfortunately did not arrive soon enough to be analyzed for inclusion in this report.

The wastewater treatment facilities for the proposed plant are to include a cyanide stripper, ammonia stripper, an activated sludge unit, clarifiers, an incinerator for stripped ammonia and cyanide, and a cooling tower for the

TABLE 4-4. WASTEWATER PRETREATMENT STANDARDS FOR NO. 11 BATTERY

Maximum flow - 1563 liters/min (413 Gal/min)

pH - 6.0 to 9.0

	Concentration[8] mg/ℓ	Effluent weight[8] Kg/day(lb/day)	Pretreatment standards for existing sources* kg/day(lb/day)
BOD	115	264 (580)	- -
COD	365	824 (1,813)	- -
NH_3 total	60	136 (300)	73 (161)
CN^- total	3	6.4 (14)	19.5 (43)
Phenol	0.2	0.45 (1)	48.9 (107.5)
TDS	5,060	11,409 (25,100)	- -
TSS	100	225 (495)	- -

* Regulations promulgated Federal Register, May 27, 1982. Average daily value for 30 consecutive days, based on 2273 tonnes (2500 tons) of coke/day production.

TABLE 4-5. EQUALIZATION TANK EFFLUENT NO. 11 BATTERY[9]

Parameter	Parameter level
pH	--
TOC (mg/ℓ)	1,400
NH_3, Free (mg/ℓ)	125
NH_3, Fixed (mg/ℓ)	135
CN (mg/ℓ)	6.7
Oil (mg/ℓ)	18
Specific conditions (μ mhos @ 25° C)	12,660
SS (mg/ℓ)	1,280
SCN (mg/ℓ)	510
Cl (mg/ℓ)	3,730
Phenol (mg/ℓ)	1,810

non-contact cooling water. While these facilities suggest a good plan, there is no way of evaluating it. It is important to realize the significance of the wastewater treatment aspect of formcoking because in the steam/oxygen mode, the quantities of wastewater requiring treatment are up to 50 percent more than produced by conventional coking. This subject is discussed further in Section 5.

Plans for handling of solid wastes generated in the proposed plant have not been fully developed either. Though many of the solid recovery operations reintroduce the recovered material to the process, there are several that do not. In particular, solids dredged from the decanters, ammonia stripper sludge, cyanide stripper sludge, and sludge from the activated sludge clarifiers are such wastes falling under the Resource Conservation and Recovery Act Regulation 3002. Some of the above would undoubtedly be categorized as hazardous wastes. Processing for reuse is a preferable approach to handling them. Inland indicated the activated sludge could be burned or sent to the coke plant for recycle.[5] FMC personnel suggested the possibility of recycle for decanter sludge, though it is not presently practiced. As in the case of wastewater treatment, sludge handling is important because the formcoke process is expected to generate much more than conventional coking. This subject is discussed further in Section 5.

5.0 ENVIRONMENTAL ASPECTS - FORMCOKING VERSUS CONVENTIONAL COKING

5.1 GENERAL

Many of the reports written about formed coke, shaped coke, molded coke, or "clean coke" have claimed an improved plant environment as compared to conventional byproduct coking. However, it is not clear whether these comparisons were made with a conventional battery with the best available pollution control technology applied, or a battery somewhere between uncontrolled and well controlled. Certainly the most obvious benefit of the formcoke processes would be the complete enclosure of the solid material from entry as ground coal to the discharge of char (calcinate) into the briquetting mixers. The absence of the brownish-yellow plumes occurring when coal is charged to a slot oven, similar emissions from leaking slot oven doors, the fiery sometimes smoky discharge of coke into the quench car, and the white plume from quenched coke are all missing in formcoking. There is a definite advantage in conveying the solids pneumatically from one process vessel to the next, and in keeping the vessels tightly sealed during the emanation of light and heavy organics from coal.

The emissions of hazardous air pollution from conventional coke production in slotted ovens can be effectively controlled with relatively new batteries, skilled workers, and comprehensive work practice and maintenance programs. Unfortunately, it may be more difficult to maintain effective emission controls as a battery ages. Skilled workers may not be available in some facilities, and effective work practices from an environmental viewpoint could concievably lead to unacceptable levels of worker exposure to hazardous emissions.

One of the major advantages of the formed coke process is that the environmental controls are not directly related to the effectiveness of work practice. This factor alone would tend to suggest that the emission controls of the proposed Inland process would be more consistent and dependable. Another major advantage of the formed coke process is that the performance is not closely related to the age of the plant. Since conventional coke ovens dimensionally change somewhat with age, alignment and other problems can develop which cause excess emissions until the problem can be corrected.

From the standpoint of direct observations, the front end (pyrolysis steps) of the FMC plant in Kemmerer looked very clean during the February, 1980 plant visit. There was evidence of some fugitive emissions in the briquette mixer area, at the conveyor transfer point and grizzly upstream of the curing oven, and around the coking kiln (perhaps airlocks). None of these appeared to be significant in terms of total quantity emitted. What was of more concern was the faint yellow coloration of the fugitives at the grizzly, suggesting the presence of organics. Tar being present in the warm green briquettes would provide the potential for organic emissions.

All of the previous discussion in this section has pertained to process air pollution. A complete environmental assessment must consider the discharges to water and land as well, and the severity of discharges to these media are less easily verified visually. The proposed Inland plant will discharge to both these media, whereas the FMC plant discharged to land only. On the basis of feasibility study data supplied by Davy-McKee, both the wastewater and solids discharges will be larger from formcoking than from conventional coking. Data to support this statement will be provided in the subsequent discussions. If the statement is true, the following question must be asked. Are what exist as air pollution problems in conventional coking converted to water or solid waste problems with formcoking? More definitive wastewater and solid waste data from the FMC plant are needed to attempt an answer to this question. On the basis of available data and literature sources the followng comparisons between conventional coking and formcoking have been made.

5.2 COMPARISON OF CRITERIA AIR POLLUTANTS

Table 5-1 presents a comparison of particulate discharges from each process. Estimates for uncontrolled conventional coking are based mostly on emission factors published in a recent EPA report.[10] Pushing emissions, both controlled and uncontrolled, are based on Reference 10 data plus data obtained by York Research Corporation on the Minister Stein system at Allied Chemical's coke plant in Ashland, Kentucky. Other controlled emission factors are based on data in Reference 10 and/or efficiency estimates noted in parenthesis. The formcoke estimates for FMC are based on experience at the FMC plant reported in Table 4-2.

TABLE 5-1. COMPARISON OF PARTICULATE EMISSIONS

Source	Conventional coking kg/Mg coke Uncontrolled	Controlled
Preheating	5.0[10]	0.5[10]
Charging	0.6[10]	0.03 (95%)[10]
Door leaks	0.3[10]	0.01 (97%)
Pushing	1.0	0.02
Quenching	0.2[10]	0.1 (50%)
Combustion stack	0.4[10]	0.04 (90%)
TOTAL	7.5	0.7

	Formcoking		
FMC Plant	kg/Mg coke	Inland Plant	Estimated-kg/Mg coke
Front end afterburner	4.8	Coal dryer and coal handling	0.05
Back end afterburner	0.66	Incinerator and byproduct gas combustion	0.82
Calcinate silo	0.19		
Calcinate surge bin	----	Coke end fugitives (must use baghouse)	0.24
Back end baghouse	0.47	Calcinate storage	0.02
Briquette cyclones	0.91		
Vent condenser	0.15		
TOTAL	7.18		1.13

Combining the FMC experience with estimates of improved particulate control is the basis of estimates presented for Inland. The coal dryer is based on the NSPS for coal dryers (about 0.03 kg/Mg) plus a controlled emission factor of 0.015 kg/Mg for coal preparation and handling at FMC.[5] The remainder of estimates for Inland are based on calculated dust concentrations for the FMC plant systems plus an assumption that a level of 50 milligrams/m^3 is achievable with the more efficient collection devices proposed for Inland.

As is evident from Table 5-1, the uncontrolled conventional coking emissions are about the same as the controlled particulate emissions at the FMC plant. The highest single source for the FMC plant is the front end afterburner. Based on the calculated particulate concentration (over 0.6 g/m^3), it is clear this does not approach the levels achievable with high efficiency collectors. It can be safely presumed that a high efficiency particulate collection device could easily lower the front end incinerator particulate by one order of magnitude.

Applying similar reasoning to the other particulate sources yields an estimate of 1.1 kg/Mg of coke for the proposed Inland plant particulate emissions. On a controlled basis, the conventional coking and formcoking particulate emissions are about equivalent considering the accuracy of the factors used. The controlled emission estimates for conventional coking represent an ideal case where all sources are well controlled. It is not known whether any conventional battery fits this ideal case. An additional important factor is that good emission control for charging, topside leaks, and door leaks for conventional batteries is strongly dependent on work practices (stage charging, door cleaning, etc.). No corresponding strong dependency is seen for formcoking. Therefore, overall particulate emission control (and organics as well) would be subject to greater variation and perhaps more frequent abnormalities in conventional coking as compared to formcoking.

In terms of sulfur oxides emitted, the two processes can be about equivalent as well. This presumes both waste gas streams can be desulfurized to the same extent. One reason why formcoking might not do as well is that more carbonyl sulfide (COS) may be formed in the fluidized beds because more oxygen is available to react than in conventional coking. There are a number of desulfurizing systems that will not remove COS. Stretford, the proposed Inland system, is one of these. On the other hand at least one - Sulfiban -

is capable of removing COS. Depending on system design the two coking process SO_x emissions can be equivalent.

A prediction of overall NO_x emissions for the formcoke process is not possible at this time. There are many combustion sources within the process whose operating conditions must be more clearly defined to allow such a prediction. What is clearly evident is that the proposed Inland plant will incinerate ammonia, as does the existing FMC plant. This one source would produce more NO_x than the limit would allow for a minimum sized gas burner (250 million BTU per hour heat input) about 1 kg/Mg coke. Table 5-2 presents the comparison between conventional coking and formcoking for ammonia processing. The ammonia generation rate for formcoking is shown as a range. The lower number, 1.5 kg/Mg coke, is based on data supplied by Inland Steel for the formcoke process.[11] The lower process temperatures are thought to contribute to lower rates of ammonia formation with formcoking. The higher number, 5.4 kg/Mg coke, assumes the same rate of ammonia generation per tonne of coal charged for formcoking as conventional coking. The table reflects higher NO_x emissions from formcoking because common industry practice for conventional coking is to recover ammonia. Some newer conventional plants, however, do incinerate ammonia also.

Ammonia could be recovered from formcoking gases just as in the case of conventional coking. In this case, NO_x from ammonia would be zero for formcoking as well.

5.3 ORGANIC AIR EMISSIONS

Hydrocarbons are of concern as they relate to photochemical smog. Even more important is the benzene and polycyclic organic matter, as they are suspected hazardous pollutants with serious health effects. Some measurements of benzene and polycyclics (particularly benzo(a)pyrene) have been made for conventional coking due to EPA's present intention of setting hazardous air pollutant standards. No similar data for formcoking have been found. These are essential to a fair assessment and comparison.

An indirect suggestion of reduced polycyclic emissions from formcoking as compared to conventional coking is provided in a recent technical paper.[4] FMC has taken data on worker exposures to benzene soluble organics to examine the plant's standing with respect to the OSHA standard of 150 micrograms per cubic

TABLE 5-2. A COMPARISON OF POTENTIAL NO_x EMISSIONS FROM AMMONIA PROCESSING

	kg/Mg coke	
	Formcoking process	Conventional process
NH_3 (production)	1.5[11]-5.4[a]	5.0
$(NH_4)_2SO_4$ produced	0.0	18.5
NO_x (as NO_2)	4-14[b]	0.0[c]

[a]Assumes similar ammonia production per unit weight of coal charged for formcoke process as for conventional process.

[b]Both the FMC and proposed Inland plant will incinerate ammonia. NO_x emissions could be zero if it were recovered instead.

[c]If ammonia from conventional coking were incinerated the NO_x produced would be 13 kg/Mg coke.

meter. These data are, in general, better than those taken in recent inspections of conventional coke plants. This conclusion is drawn in reference to sets of measurements made for OSHA inspections in three conventional coke plants.[12] Table 5-3 presents a comparison of the FMC plant measurements with several from conventional coking. It must be recognized that the relationship between worker exposure levels and pollutant emission rates is complex and that the trend in one may not be a good indicator of the trend in the other. It is tempting to suggest the lower worker exposures mean lower emission rates are occurring, but that may not necessarily be true. Workers can use respirators, and air conditioned-filtered air rest stations and control rooms to avoid exposure. In any case from an occupational exposure standpoint formcoking appears to offer an advantage.

A further suggestion of lower hazardous emissions is contained in a Russian paper.[13] Measurement of benzopyrene concentrations in the working environment atmosphere were made in a "molded coke" pilot plant and compared to conventional coking. The report noted lower benzopyrene concentrations (not over 1.1 $\mu g/m^3$) at the molded coke plant as compared to conventional coking (0.11-43.0 $\mu g/m^3$). The translation of the reference is not completely clear, but there was an additional conclusion that apparently lower amounts (one order of magnitude) of benzopyrene occur in the tar emissions from molded coking as opposed to conventional coking.

5.4 WASTEWATER AND SOLID WASTE DISCHARGES

Table 5-4 presents a comparison of wastewater discharges for treatment between formcoking and conventional coking. Inland is not planning to recover all light oil (benzene) materials from formcoking. However, to make the comparison on a common basis byproduct wastewater must be added to formcoking (or subtracted from conventional coking). When byproduct recovery wastewater is included, the wastewater treatment quantities are about 50 percent higher for formcoking in the steam/oxygen mode than for conventional coking.

Presumably wastewater treatment can be designed to provide the same quality of discharge possible from a conventional plant, however, the overall size will have to be increased. An additional important point is that most plants do not have the opportunity of discharging wastewater to a publicly owned treatment works as Inland can. Those plants will have to provide complete wastewater treatment. That could be a significant impact to the overall process economics.

TABLE 5-3. WORKER EXPOSURES TO BENZENE SOLUBLE ORGANICS[4,12]

Job class	Formcoking Avg. exposure µg/m³	Job Class	Conventional coking Avg. exposure µg/m³			
			Republic-Cleveland		USS-Clairton	
			Batt 1	Batt 2	Batt 7	Batt 8
Maintenance man	50	Door cleaner	169	290	490	200
A-operator	80	Lidman	252	435	350	210
Coal handler	100	Top workers	259	273	220	190
Laborer	141	Side workers	216	291	370	170
Tar operator	73	Larry car operator	241	404	---	---
Briquetter operator	161	Machine workers	166	221	---	---
Foreman	72					
Kiln legman	137					
Fluid plant legman	106					

TABLE 5-4. A COMPARISON OF WASTEWATER FROM THE FORMCOKING AND CONVENTIONAL COKING

	kg/Mg coke	
	Air Mode	Steam/O_2 Mode
Calcinate thickener	0	187
Calcinate thickener sludge	136	198
Product gas treatment - coking kiln	48	48
Product gas treatment - carbonizer		
venturi scrubber	13	161
scrub tower, light oil skimmer	106	486
TOTAL[a]	303	1,080
Conventional coke		
Excess ammonia liquor	100-200	
Stage charging	16	
Desulfurization wastewater (Vacuum carbonate)	40-60	
Benzene recovery (final cooler blowdown, light oil plant)	143-930	
Ammonia recovery	143	
Preheater scrubber blowdown	110	
TOTAL	550-1460	

[a]The formcoke process is expected to have similar volumes of wastewater from desulfurization, benzene recovery, and ammonia recovery as conventional coking. This was not included in Table 5-4 and is expected to be in the range of 330 to 1,130 kg/Mg.

Table 5-5 presents the comparative solid wastes emissions. There are four major solid wastes generated by conventional coking. The largest quantity is coke breeze. While coke breeze has been presented as a solid waste from conventional coking, it is common for most of this material to be used elsewhere in the iron and steelmaking process or to be sold for its fuel value since it is about 80 to 90 percent carbon by weight.[14] Coke breeze is used within the steel plants in sinter plant feed mixtures and for soaking bottoms. Other sources of sludges in the byproduct recovery plant are the tar decanter sludge and lime leg sludge, and the wastewater treatment sludge from the biological treatment plant. The tar decanter sludge is hazardous because it contains polycyclic organic material. The lime leg sludge is produced by releasing ammonia from the ammonia liquor by adding lime.

The calcinate thickener sludge is the major source of solid waste in formcoking. No use for this sludge/solid waste has yet been identified. This sludge would be dewatered and trucked to a landfill. This sludge could conceivably be recycled after drying in the process, although this may not be desirable alternative because of the relatively high ash content.

Since formcoking may produce larger amounts of wastewater than conventional coking, the potential for sludge formation is correspondingly greater. The magnitude of these solid wastes as well as their potential toxic properties have not been determined.

5.5 TRACE ELEMENT RECOVERY IN FORMCOKE PROCESS

The coal which is used in the formcoke process contains small amounts of trace elements which are considered environmentally undesirable. These include mercury, selenium, arsenic, lead, and other heavy metals. As the coal is heated in the various process units, some of these heavy metals will be volatilized and enter the gas streams. The volatilized elements can then collect on particulates, be absorbed into water streams, collect in tars, and some of them may remain in the product gas stream.

The amount of trace elements which are emitted from the coal in fluidized beds is expected to be potentially greater than the amounts of elements emitted from conventional slot-oven coking. Two reasons which tend to suggest that the emissions could be greater are the large surface area of the coal in the fluidized bed and the volume of particulates which are emitted from the process. The particulates are leached by the scrubber water. To assess the

TABLE 5-5. A COMPARISON OF THE RATES OF SOLID WASTE GENERATION IN FORMCOKING AND CONVENTIONAL COKING

Waste	Rate (kg/Mg) Conventional	Formcoking Air	Formcoking Steam/O_2
Calcinate thickener sludge	0	24.4	19.8
Wastewater treatment sludge	1.7	2.5[a]	2.5[a]
Tar decanter sludge	0.1	0.1	0.1
Lime leg sludge	0.35	0.5[a]	0.5[a]
Scrubbing tower blowdown - carbonizer	----	1.6	1.1
Coke breeze	36[14]	----	----
TOTAL	38[b]	29.1	24.0

[a]Estimated to be 50 percent greater than conventional coking because of increased amount of wastewater to be treated.

[b]Most of the coke breeze is used in the steel plant or sold to others.

potential environmental significance of the formcoke process, data has been selected from gasification investigations which are similar in some aspects to the fluidized formcoke process. These studies are not presented as an indication of effects which will occur in the formcoke process, but merely as indication of trace element pollution which may occur.

Arsenic, mercury, cadmium, lead and selenium are examples of elements which are potentially present in the product gas streams. A very substantial amount of these elements are expected to be removed in the gas cleaning steps, however. Table 5-6 presents some theoretical emissions of elements which could be expected from a hypothetical coal mix. Table 5-6 indicates total hypothetical emissions to the particulates which are collected, the wastewater, the tars, and to a lesser extent, the product gas.

Table 5-7 presents the trace elements recovery in gasification water for two commercial processes. Significant concentrations of various volatile elements were identified in the wastewater streams. The percent recovery of the elements which were in the original coal is presented in Table 5-7. Table 5-8 presents trace element recovery and gasification water from Research Triangle Institute gasification tests. Differences between Illinois bituminous coal and Wyoming subbituminous coal are presented. Other elements than those in Tables 5-7 and 5-8 were identified in the wastewater but these elements are considered to be among the most significant environmentally among the ones which were identified.

Conventional coke ovens also produce elements in the product gas which are formed from the heating of coal in the slot ovens. These are important as a potential wastewater treatment problem and also as a process problem. The product gas stream in conventional byproduct ovens is cooled by a direct water final cooler in many process systems. Complete recycle of this cooling water is not possible due to the build up of chlorine in the water which can cause severe corrosion problems in the process equipment. A similar recycling of cooling water for the venturi scrubbers is proposed for the Inland process. This recyling of process water will very significantly reduce the volume of wastewater which will require treatment, but it will also increase the concentraions of elements which are collected in the wastewater. Elements such as selenium and arsenic can reach significant concentrations.

The environmental impact of elements which may concentrate in the wastewater has not been determined. The ultimate treatment level which may be

TABLE 5-6. TRACE ELEMENTS - ESTIMATED VOLATILITY

Element	%Volatile*	Hypothetical coal ppm[1]	Emission rate** kg/day	(lb/day)
Cl	90+	1500	2,045	(4500)
Hg	90+	0.3	0.5	(1)
Se	74	1.7	1.8	(4)
As	65	9.6	9.5	(21)
Pb	63	5.9	5.5	(12)
Cd	62	0.8	0.9	(2)
Sb	33	0.2	0.1	(0.2)
V	30	33	15	(33)
Ni	24	12	4.5	(10)
Be	18	0.9	0.2	(0.5)
Zn	10	44	6.8	(15)
B	10	165	25	(55)
F	10	85	13.2	(29)
Ti	10	340	51.4	(114)
Cr	--	15	--	

*Volatility based mainly on gasification experiments but chlorine is taken from combustion tests, while zinc, boron, and fluorine were taken at 10 percent for illustration in absence of data. Reference 15, 16.

**Based upon the design capacity of 63,640 kg/day (140,000 lb/hr).

TABLE 5-7. TRACE ELEMENT RECOVERY IN GASIFICATION WATER FOR TWO COMMERCIAL PROCESSES

Element	Synthane[17] Illinois bituminous µg/mL	Synthane[17] Illinois bituminous % recovery	Lurgi[18] Montana subbituminous µg/mL	Lurgi[18] Montana subbituminous % recovery
Arsenic	0.001	0.2	0.014	2.0
	0.001	<0.2		
	0.001	0.1		
Beryllium	---	0	0.22	27
Cadmium	---	---	0.1	19
Chromium	0.043	0.1	1.3	12
	0.004	0		
	0.006	0		
Lead	0.003	0.7	0.12	2
	0.002	0.3		
	---	0		
Manganese	0.20	0.20	0.01	0.30
	0.1	0.0		
	0.014	0.0		
Mercury	0.027	39	0.056	37
	0.029	36		
	0.03	47		
Selenium	0.14	9.6	0.05	14.1
	0.002	1.1		
	0.18	41		

TABLE 5-8. TRACE ELEMENT RECOVERY IN GASIFICATION WATER
RTI GASIFICATION TESTS

Element	Illinois bituminous		Wyoming subbituminous	
	Conc. µg/mL	% recovery	Conc. µg/mL	% recovery
Arsenic	0.23	16	0.01	0.7
	0.14	5	1.1	51
	1.0	45		
	1.8	24		
Cadmium	0.004	12	0.015	22
	0.0001	0.2		
	0.002	7.5		
	0.002	3.3		
Chromium	0.29	3.6	2.7	
	0.35	2.9		
	2.31	29		
	2.41	8		
Lead	0.03	2.8	0.021	7.8
	0.012	0.7	0.18	4.8
	0.44	2.7		
Selenium	0.36	39	0.066	23
	0.8	30		

required under the Resource Recovery and Conservation Act is currently undefined.

Table 5-9 contrasts the trace element concentrations in conventional coking operations to concentrations which were obtained from one gasification process. Although the RTI tests were done with Illinois bituminous coal, the concentrations could not be related to the proposed formcoke process with any degree of confidence due to process differences, coal differences, recycle rates, and other factors. Table 5-9 does indicate that contamination of formcoke wastewater beyond the levels of conventional coking is possible, and trace element contamination should be considered as a potential environmental consequence of the conversion to formcoke production.

TABLE 5-9. A COMPARISON OF TRACE ELEMENTS IN THE WASTEWATER OF INLAND BATTERY NO. 11 AND RTI GASIFICATION TESTS

Element	Concentration µg/mL	
	Battery	Gasification
Cadmium	0.03	0.0001-0.004
Chromium	0.02	0.29-2.4
Lead	0.002	0.012-0.44
Selenium	0.023	0.36-0.8

6.0 DATA GAPS

Many of the potential pollutant streams in the proposed formcoke process have not been characterized in sufficient detail to provide an overall assessment of the environmental impact of the process. The proposed Inland plant would have been the first full scale demonstration of a process to replace conventional coking in an integrated steel plant. Conventional coking has known environmental hazards. Before replacing conventional coking on an industry wide basis, much more must be known about the environmental aspects of the process. This would avoid the possibility of wholesale conversions to a process less environmentally acceptable. The pollutants of concern are benzene, polynuclear aromatic compounds, various organic compounds, oxides of nitrogen, sulfur compounds, and trace elements. Potentially significant pollutants are expected for air, wastewater, and solid waste which are produced by the process.

Benzene is expected to be present in the exhaust from the coal dryer, the wastewaster, and in various uncontrolled vents in the binder preparation and light oil processing area.

Polynuclear aromatics are potentially present in the incinerator and boiler exhaust stacks, as well as the gaseous from various tar and binder preparation and curing steps. Various organic compounds are potentially present in the exhaust from particulate control devices, as well as in the wastewater effluents.

The concentrations of sulfur containing compounds and oxides of nitrogen is needed for the combustion exhaust as well as some of the process exhaust. Limited design information is available to estimate the magnitude of these emissions, but acutal measurements are required for more complete environmental assessment.

The presence of trace elements in the wastewater effluents, the solid waste, and the atmospheric exhaust are necessary. These elements are expected to constitute a significant impact to the environment and adequate documentation of the fate of these elements in the formcoke process is not available.

An environmental assessment of exhaust gases from process units such as a catalyzer is particularly important when the level of pollutants in the exhaust cannot be predicted by averaged conditions since localized regions of high temperature could exist in the unit. These zones of high temperature could produce greater levels of pollutants than expected from the average temperatures. Documentation of potential environmental problems from the toxic elements, dissolved ammonia and cyanides, as well as organic material in the wastewater streams are important since this information can be used to identify the level of treatment which may be necessary.

Table 6-1 identifies some of the major sources of emissions in the form-coke process and indicates the types of pollutants which may be present. Some of these are expected to be potentially signficant based on preliminary study.

TABLE 6-1. POTENTIAL SOURCES OF ENVIRONMENTAL EMISSIONS

Source	Pollutant
Coal dryer venturi scrubber	B, PNA, O, NO_x
Incinerator exhaust	TE, S. NO_x, PNA
Calciner cooler cyclone exhaust	PNA, S, TE, O
Calcinate silo baghouse	TE, PNA, B, S, O
Briquette cyclone exhaust	PNA, O
Curing oven screen cyclone	PNA, O
Coke handling transfer points	PNA, TE, O
Cooler conveyor cyclone	PNA, TE, O
Boiler stack	TE, PNA, S, NO_x
Calcinate thickener sludge	TE, PNA, O
Calcinate thickener effluent	B, PNA, O, TE, A
Tar decanter effluent	B, PNA, O, TE, A
Binder storage vent	B, PNA, O
Supplementary binder vent	B, PNA, O
Skimmer vent	B, PNA, O
Light oil storage	B, PNA, O

POLLUTANT CODE

A	ammonia	S	sulfur
B	benzene	O	organics
PNA	polynuclear aromatic	NO_x	oxides of nitrogen
TE	trace elements		

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